भारतीय मानक

Indian Standard

IS/ISO 8528-3 : 2020

प्रत्यागामी आंतरिक दहन इंजन चालित प्रत्यावर्ती धारा करंट जनरेटिंग सेट

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(पहला पुनरीक्षण)

Reciprocating Internal Combustion Engine Driven Alternating Current Generating Sets

Part 3 Alternating Current Generators for Generating Sets

(First Revision)

ICS 27.020; 29.160.40; 29.160.20

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NATIONAL FOREWORD

This Indian Standard (Part 3) (First Revision) which is identical with ISO 8528-3 : 2020 'Reciprocating internal combustion engine driven alternating current generating sets — Part 3 : Alternating current generators for generating sets' issued by International Organization for Standardization (ISO) was adopted by the Bureau of Indian Standards on the recommendations of the Automotive Prime Movers, Transmission Systems and Internal Combustion Engines Sectional Committee and approval of the Transport Engineering Division Council.

This standard was first published in 2012 as IS/ISO 8527-3 : 2005. This first revision has been undertaken to harmonize it with ISO 8528-3 : 2020. The main changes compared to the previous edition are as follows:

a) Clause **7** (ISO 8528-3 : 2005, clause **9**) has been updated with requirements for isochronous operation and grid parallel operation;

b) Requirements for asynchronous generators have been integrated in Clause **8** (ISO 8528-3 : 2005, clause **10**);

c) New power rating 'GPO' has been introduced for grid parallel operation;

d) Operating limits have been revised;

e) New clauses have been added for specifying 'bearings' and 'maintenance'; and

f) Identification markings BR and PR have been eliminated.

This Indian Standard has been published in several parts. Other parts in this series are:

Part 1	Applications, ratings and performance
Part 2	Engines
Part 4	Control gear and switch gear
Part 5	Generating sets
Part 6	Test methods
Part 7	Technical declarations for specification and design
Part 8	Requirements and tests for low-power generating sets
Part 9	Measurement and evaluation of mechanical vibration
Part 10	Measurement of airborne noise by the enveloping surface method
Part 12	Emergency power supply to safety services

The text of the ISO standard has been approved as suitable for publication as Indian Standard without deviations. Certain conventions are, however, not identical to those used in Indian Standard. Attention is particularly drawn to the following:

a) Wherever the words 'International Standard' appear referring to this standard, they should be read as 'Indian Standard'.
b) Comma (,) has been used as a decimal marker while in Indian Standards, the current practice is to use a point (.) as the decimal marker.

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Indian Standard

RECIPROCATING INTERNAL COMBUSTION ENGINE DRIVEN ALTERNATING CURRENT GENERATING SETS

PART 3 ALTERNATING CURRENT GENERATORS FOR GENERATING SETS

(First Revision)

1 Scope

This document specifies the principal characteristics of alternating current (a.c.) generators under the control of their excitation control system when used for reciprocating internal combustion (RIC) engine driven generating set applications and supplements the requirements given in IEC 60034-1. It covers the use of such a.c. generators for land and marine applications, excluding generating sets used on aircraft or to propel land vehicles and locomotives.

NOTE For some specific applications (e.g. essential hospital supplies, high-rise buildings, operation parallel with the grid), supplementary requirements can be necessary. The provisions of this document can be regarded as the basis for establishing any supplementary requirements.

For a.c. generating sets driven by other reciprocating-type prime movers (e.g. steam engines) the provisions of this document can be used as basis for establishing these requirements.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 281, *Rolling bearings — Dynamic load ratings and rating life*

ISO 8528-1:2018, *Reciprocating internal combustion engine driven alternating current generating sets — Part 1: Application, ratings and performance*

IEC 60034-1:2017, *Rotating electrical machines — Part 1: Rating and performance*

IEC 60034-5, *Rotating electrical machines — Part 5: Degrees of protection provided by the integral design of rotating machines (IP code) — Classification*

IEC 60034-6, *Rotating electrical machines — Part 6: Methods of cooling (IC code)*

IEC 60034-7, *Rotating electrical machines — Part 7: Classification of types of construction, mounting arrangements and terminal box position (IM code)*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at http://www.electropedia.org/

NOTE 1 This document uses suffix "r" for "rated" whereas in IEC standards the suffix "N" is used.

NOTE 2 Voltage terms relate to an a.c. generator running at constant (rated) speed under the control of the normal excitation and voltage control system.

3.1
rated output
S_r
product of the rated rms voltage, the rated rms current and a constant *m*

Note 1 to entry: Where

— $m = 1$ for single-phase;

— $m=\sqrt{2}$ for two-phase;

— $m=\sqrt{3}$ for three-phase.

Note 2 to entry: $\sqrt{2}$ is applicable only when the a.c. generator is specifically designed in two-phase, an angle of 90° electrical between the two poles.

Note 3 to entry: S_r is expressed in volt-amperes (VA) or its multiples.

3.2
rated active power
P_r
product of the rated rms voltage, the in-phase component of the rated rms current and a constant *m*

Note 1 to entry: Where

— $m = 1$ for single-phase;

— $m=\sqrt{2}$ for two-phase;

— $m=\sqrt{3}$ for three-phase.

Note 2 to entry: $\sqrt{2}$ is applicable only when the a.c. generator is specifically designed in two-phase, an angle of 90° electrical between the two poles.

Note 3 to entry: P_r is expressed in watts (W) or its decimal multiples.

3.3
rated power factor
$\cos \varphi_r$
ratio of the *rated active power* (3.2) to the *rated output* (3.1)

Note 1 to entry: $\cos\varphi_r = \frac{P_r}{S_r}$.

3.4
rated speed
n_r
speed of rotation necessary for voltage generation at rated frequency

Note 1 to entry: n_r is expressed in revolution per minute (min^{-1}).

3.5
rated voltage
U_r
line-to-line voltage at the terminals of the a.c. generator at rated frequency and at *rated output* (3.1)

Note 1 to entry: Rated voltage is the voltage assigned by the a.c. generator manufacturer for operating and performance characteristics.

Note 2 to entry: U_r is expressed in volts (V) or its decimal multiples.

3.6
no-load voltage
U_0
line-to-line voltage at the terminals of the a.c. generator at rated frequency and no-load

Note 1 to entry: U_0 is expressed in volts (V) or its decimal multiples.

3.7
operating voltage
U_c
value of the voltage under normal conditions at a given instant and given point of the system

Note 1 to entry: U_c is expressed in volts (V) or its decimal multiples.

Note 2 to entry: This value can be expected, estimated or measured.

[SOURCE: IEC 60050-601:1985, 601-01-22, modified — The symbol and Note 1 to entry have been added.]

3.8
voltage recovery
U_{rec}
restoration of voltage to a value near to its previous value after a reduction of the voltage or a loss of voltage

Note 1 to entry: U_{rec} is expressed in volts (V) or its decimal multiples. Recovery voltage is normally expressed as a percentage of the *rated voltage* (3.5). For loads more than rated, recovery voltage is limited by saturation and exciter-regulator field forcing capability.

[SOURCE: IEC 60050-614:2016, 614-01-27, modified — The symbol and Note 1 to entry have been added.]

3.9
range of voltage setting
ΔU_s
range of possible upward and downward adjustment of voltage at a.c. generator terminals at rated frequency, for all loads between no-load and *rated output* (3.1)

Note 1 to entry: $\Delta U_s = \left|\Delta U_{s,up}\right| + \left|\Delta U_{s,do}\right|$

$$\Delta U_{s,up} = \frac{U_{s,up} - U_r}{U_r} \cdot 100\%$$

$$\Delta U_{s,do} = \frac{U_{s,do} - U_r}{U_r} \cdot 100\%$$

where

$\Delta U_{s,up}$ is the upward range of voltage setting;

$\Delta U_{s,do}$ is the downward range of voltage setting;

$U_{s,up}$ is the upward adjustable limit for voltage settings, expressed in volts (V) or its decimal multiples;

$U_{s,do}$ is the downward adjustable limit for voltage settings, expressed in volts (V) or its decimal multiples.

Note 2 to entry: ΔU_s is expressed as a percentage of the *rated voltage* (3.5).

Note 3 to entry: Special controllable excitation equipment can provide a range of voltage adjustment for asynchronous generators.

3.10
steady-state voltage tolerance band
ΔU
agreed voltage band about the steady-state voltage that the voltage can reach within a given *voltage recovery time after load decrease* (3.15) or *voltage recovery time after load increase* (3.16)

Note 1 to entry: $\Delta U = 2 \cdot \Delta U_{st} \cdot \frac{U_r}{100}$.

Note 2 to entry: ΔU is expressed in volts (V) or its decimal multiples.

3.11
steady-state voltage deviation
ΔU_{st}
change in steady-state voltage for all load changes between no-load and *rated output* (3.1), considering the influence of temperature but ignoring the effect of quadrature current compensation voltage droop

Note 1 to entry: $\Delta U_{st} = \pm \frac{U_{st,max} - U_{st,min}}{2 \cdot U_r} \cdot 100\,\%$

where

$U_{st,max}$ is the maximum steady-state voltage deviation, expressed in volts (V) or its decimal multiples;

$U_{st,min}$ is the minimum steady-state voltage deviation, expressed in volts (V) or its decimal multiples.

Note 2 to entry: The initial set voltage is usually the *rated voltage* (3.5) but can be anywhere within the range of voltage setting.

Note 3 to entry: ΔU_{st} is expressed as a percentage of the rated voltage.

3.12
transient voltage drop
ΔU_{dyn}^{-}
maximum voltage drop, when the a.c. generator, driven at the *rated speed* (3.4) and at the *rated voltage* (3.5) under normal excitation control, is switched onto a symmetrical load which absorbs a specified current at the *rated voltage* (3.5) at a given power factor or range of power factors

Note 1 to entry: $\Delta U_{dyn}^{-} = \frac{U_{dyn,min} - U_r}{U_r} \cdot 100\,\%$

where $U_{dyn,min}$ is the minimum downward transient voltage on load increase, expressed in volts (V) or its decimal multiples.

Note 2 to entry: ΔU_{dyn}^{-} is expressed as a percentage of the rated voltage.

Note 3 to entry: see Figure A.2.

3.13
transient voltage rise
ΔU_{dyn}^{+}
maximum voltage rise, when the a.c. generator, driven at the *rated speed* (3.4) and at the *rated voltage* (3.5) under normal excitation control, has a sudden rejection of the *rated output* (3.1)

Note 1 to entry: $\Delta U_{dyn}^{+} = \frac{U_{dyn,max} - U_r}{U_r} \cdot 100\,\%$

where $U_{dyn,max}$ is the maximum upward transient voltage on load decrease, expressed in volts (V) or its decimal multiples.

Note 2 to entry: ΔU_{dyn}^{+} is expressed as a percentage of the rated voltage.

Note 3 to entry: see Figure A.3.

3.14
voltage unbalance factor
$\Delta U_{2,0}$
degree of voltage unbalance in a three-phase system

Note 1 to entry: $\Delta U_{2,0}$ is expressed as a percentage by the ratio of the rms values of the negative sequence component (or the zero-sequence component) to the positive sequence component of the fundamental component of voltage.

3.15
voltage recovery time after load decrease
$t_{u,de}$
time interval from the time at which a load decrease is initiated until the time when the voltage returns to and remains within specified *steady-state voltage tolerance band* (3.10)

Note 1 to entry: $t_{u,de}$ is expressed in seconds (s) or its decimal multiples.

Note 2 to entry: see Figure A.3.

3.16
voltage recovery time after load increase
$t_{u,in}$
time interval from the time at which a load increase is initiated until the time when the voltage returns to and remains within specified *steady-state voltage tolerance band* (3.10)

Note 1 to entry: $t_{u,in}$ is expressed in seconds (s) or its decimal multiples.

Note 2 to entry: see Figure A.2.

3.17
relative thermal life expectancy factor
T_L
relative thermal life expectancy related to the thermal life expectancy in case of duty factor S1 with *rated output* (3.1)

Note 1 to entry: See IEC 60034-1:2017, Annex A.

3.18
grade of quadrature-current compensation voltage droop
δ_{QCC}
difference between the *no-load voltage* (3.6) and the voltage at the rated current at the power factor zero overexcited $U_{(Q=S_r)}$ when running isolated

Note 1 to entry: $\delta_{QCC} = \frac{U_0 - U_{(Q=S_r)}}{U_r} \cdot 100\,\%$

Note 2 to entry: δ_{QCC} is expressed as a percentage of the *rated voltage* (3.5).

4 Abbreviated terms

An explanation of abbreviated terms used in this document is shown in Table 1.

Table 1 — Abbreviated terms

Abbreviated term	Explanation
AMC	agreement between a.c. generator manufacturer and generating set manufacturer (customer)
a.c.	alternating current
EMF	electromagnetic field
GPO	grid parallel operation
HCF	harmonic current factor
IC	international cooling
IM	international mounting
IP	international protection
RIC	reciprocating internal combustion
rms	root mean square
THD	total harmonic distortion

5 Other requirements and additional regulations

The degree of protection provided by the enclosure of the a.c. generator (IP-code) shall be specified in accordance with IEC 60034-5 and agreed between the a.c. generator manufacturer and the generating set manufacturer. The a.c. generator manufacturer shall assure, i.e. by verification or graphical analysis, that the intended degree of protection will be provided under all normal conditions of use.

The method of cooling (IC-code) shall be specified in accordance with IEC 60034-6 and agreed between the a.c. generator manufacturer and the generating set manufacturer.

The type of a.c. generator construction, mounting arrangement and terminal box position (IM-code) shall be specified in accordance with IEC 60034-7 and agreed between the a.c. generator manufacturer and the generating set manufacturer.

For a.c. generators used on board ships and offshore installations which are subject to the rules of a classification society, it is presupposed that the additional requirements of the classification society are observed. The classification society name shall be stated by the generating set manufacturer prior to placing the order.

For a.c. generators operating in non-classed equipment, such additional requirements are subject to agreement between the a.c. generator manufacturer and the generating set manufacturer.

If special requirements from any other authority (e.g. inspecting and/or legislative authorities) apply, the authority name shall be stated by the generating set manufacturer prior to placing the order.

NOTE 1 Attention is drawn to the need to take note of additional regulations or requirements imposed by various regulatory bodies. Such regulations or requirements can form the subject of agreement between the a.c. generator manufacturer and the generating set manufacturer when conditions of use of the product invoke such requirements.

NOTE 2 Examples of regulatory authorities include:

— classification societies, for generating sets used on ships and offshore installations;

— government agencies;

— inspection agencies, local utilities, etc.

6 Rating

The a.c. generator rating class shall be specified in accordance with IEC 60034-1. In the case of a.c. generators for RIC engine driven generating sets, continuous ratings (duty type S1) or ratings with discrete constant loads (duty type S10) are applicable.

7 Operation of a.c. generators

7.1 Isochronous (stand-alone) operation

Isochronous operation, i.e. stand-alone operation, refers to the a.c. generator of a generating set, irrespective of its configuration or modes of start-up and control, operating as the sole source of electrical power and without the support of other sources of electrical supply.

For a.c. generators intended to operate over a relatively small range of voltage, the rated output and rated power factor shall apply at any voltage within the range, as specified in IEC 60034-1:2017, 7.3.

In accordance with IEC 60034-1:2017, 7.2.2, three-phase a.c. generators shall be suitable for supplying circuits which, when supplied by a system of balanced and sinusoidal voltages:

a) result in currents not exceeding a harmonic current factor (f_{HCF}) of 0,05, and

b) result in a system of currents where neither the negative-sequence component nor the zero-sequence component exceeds 5 percent of the positive-sequence component.

The harmonic current factor shall be computed by using Formula (1):

$$f_{\mathrm{HCF}} = \sqrt{\sum_{n=2}^{13} i_n^2} \tag{1}$$

where

i_n is the ratio of the harmonic current (I_n) to the rated current (I_{r});

n is the order of harmonic.

If the limits of deformations and imbalance occur simultaneously during operation at the rated load, this shall not lead to any harmful temperature in the a.c. generator. It is recommended that the resulting excess temperature rise related to the limits of temperature rise as specified in IEC 60034-1 does not exceed 10 K.

7.2 Parallel operation without grid

When an a.c. generator is running in parallel with other generating sets or with another source of electrical supply, i.e. island mode or marine applications, controlling means shall be provided to ensure stable operation and correct sharing of reactive power.

Stable operation is most often affected by influencing the a.c. generator excitation control system through sensing circuit with an additional reactive current component. This causes a voltage droop characteristic to be present for reactive loads.

The grade of quadrature-current compensation voltage droop δ_{QCC} is expected to be less than 8 %. Higher values shall be considered in the case of excessive system voltage variations.

NOTE 1 Identical a.c. generators with identical excitation systems are expected to operate in parallel without requiring droop compensation when their field windings are connected by equalizer links, i.e. cross-current compensation or reactive load sharing lines. Adequate reactive load sharing is achieved when there is correct active load sharing.

NOTE 2 When generating sets are operating in parallel with star points (neutral points of generators) directly connected to other star points of generators, circulating currents can occur, particularly third harmonic current. Circulating currents can increase the rms current and reduce the thermal life expectancy of the insulation system.

Asynchronous generators with special generator control and excitation equipment running in parallel (to another such a.c. generators or to the mains), share the reactive power demand of the connected load according to the capabilities of their excitation systems.

Asynchronous generators share the active power demand of the connected load according to the speed of the RIC engine.

7.3 Parallel operation with grid

7.3.1 General

When an a.c. generator is running in parallel with a public network, it is presupposed that the generating set manufacturer specifies the a.c. generator to fulfil the local grid code requirements.

NOTE 1 IEC/TS 62786 provides principles and technical requirements for generating sets connected to the distribution network.

Means shall be provided to ensure stable operation and correct reactive power sharing. Often this performance is affected by several auxiliary control functions of the a.c generator excitation control system. To obtain reliable results, the a.c. generator manufacturer can be required to provide all generator relevant quantities (including peak value of short circuit current of a generator under specified conditions) and exciter parameters. The tolerance of the parameter shall be agreed between the a.c. generator manufacturer and the generating set manufacturer.

NOTE 2 For some simulations, tolerance of ±30 % for peak value of short-circuit current of an a.c. generator under specified excitation (IEC 60034-1:2017, Table 21) is too wide. Stability simulations demand higher accuracy, i.e. ±15 % of the value, to obtain reliable results.

NOTE 3 At the request of the relevant system operator, the power-generating facility owner is asked to provide simulation models which properly reflect the behaviour of the power-generating module in both steady-state and dynamic simulations or in transient simulations.

For synchronizing a generating set with the grid, generating set control and generator control is expected to be fully automatic. Unless otherwise agreed upon, a.c. generators shall be designed to withstand electrical and mechanical stress when coupling with another source of electrical supply by using typical limit settings of synchronization devices:

— voltage range: ±5 % U_c;

— frequency range: ±200 mHz;

— angular range: ±5° (can be extended to ±10° for fast synchronization).

NOTE 4 In an increasingly more volatile electricity market, power supply from renewable sources creates the need for generating sets with higher operational flexibility and thermo-mechanical robustness. Peaking applications with a high number of starts and stops and the capabilities for fast start-up and quick synchronization are becoming of upmost importance.

7.3.2 Excitation system

In a synchronous generator, the exciter field power can be generated for example by a permanent magnet generator, an auxiliary field winding, auxiliary power supply or shunt supply. For synchronous generators with brushless exciters, the field coil insulation and the diodes in the rectifier bridge shall be protected from overvoltage or surge events.

The engine generator assembly shall be equipped with suitable generating set control, generator control and excitation control systems able to meet the requirements of the intended context of use of the generating set when connected parallel with grid. Where the requirements of grid connection mandate the use of a digital excitation system, the generating set manufacturer shall specify the requirement to the a.c. generator manufacturer. The a.c. generator manufacturer shall supply the a.c. generator with a digital excitation system capable to meet the specified requirements.

7.3.3 Reactive power control

Where reactive power control is required, one of the following control modes is recommended to be applied by the excitation control system:

— VAR control with internal or external setpoint for reactive power;

— power factor control with internal or external setpoint for power factor;

— voltage control with internal or external setpoint for voltage.

Above options can be used independently or in combination with the following compensation methods:

— reactive voltage droop compensation (quadrature voltage droop) to minimize circulating currents between multiple a.c. generators in parallel with the grid;

— differential compensation (cross current compensation).

Reactive power control requirements shall be agreed upon between the a.c. generator manufacturer and the generating set manufacturer based on the intended application of the generating set and any applicable grid codes.

7.3.4 Limiter functions

The following limiters represent an additional protective function to prevent overloading of specific components of the generator during parallel operation with the grid:

— under- and over-excitation current limiter;

— volts per hertz (V/Hz) limiter;

— reactive power limiter;

— minimum and maximum machine voltage limiter;

— maximum machine current limiter.

7.3.5 Power system stabilizer (optional)

Various grid codes and utilities request the option to implement a "power system stabilizer". The function shall be agreed upon between the generating set manufacturer and the distribution or transmission network operator. Oscillations between a group of a.c. generators, local area oscillations and interarea oscillations range from typically 0,1 Hz to 2,0 Hz. A power system stabilizer utilizes additional input signals to the a.c. generator excitation system to introduce further positive damping into the complex system comprising the synchronous generator, its excitation system and the power plant.

7.4 Effects of electromechanical vibration and its frequency

It is the responsibility of the generating set manufacturer to ensure that the generating set operate in a stable manner when connected in parallel with others and the a.c. generator manufacturer shall collaborate as necessary to achieve this.

If there is a RIC engine torque irregularity at a frequency close to the electromechanical natural frequency, resonance can occur. The electromechanical natural frequency can be calculated with synchronization power, moment of inertia of the system and firing interval of the engine.

As flicker results from the periodic fluctuation of the speed, the generating set manufacturer shall advise the a.c. generator manufacturer of engine speed characteristics such that appropriate generator can be selected.

In such cases, the generating set manufacturer shall be prepared to give advice, assisted by a system analysis if necessary, and it is expected that the a.c. generator manufacturer will assist in such investigations.

8 Special load conditions

8.1 General

In addition to the conditions given in IEC 60034-1, the requirements in 8.2 to 8.6 shall apply.

NOTE Consideration of the variation of these requirements from IEC 60034-1 will assist the specification of special load conditions.

Asynchronous generators need reactive power for voltage generation. When running in isolation, special power converter excitation control equipment is necessary to provide their excitation. This equipment also shall supply the reactive power demand of the connected load.

8.2 Unbalanced load current

For continuous operation, in accordance with IEC 60034-1:2017, 7.2.3, the ratio of negative-sequence component of current (I_2) to the rated current (I_r) shall not exceed:

— 8 % for salient pole machines and permanent magnet excited machines;

— 10 % for cylindrical rotor machines.

A.c. generators with ratings below 1 000 kVA, which are intended to be loaded between line and neutral, shall be capable of operating continuously with a negative phase sequence current up to and including 10 % of the rated current.

8.3 Sustained short-circuit current

Sustained short-circuit current is attained by the generator control and excitation system of a synchronous generator designed to provide a specified value of short-circuit current for a specified period. The value and duration of the sustained short-circuit current shall be decided by the agreement between the a.c. generator manufacturer and the generating set manufacturer. The synchronous generator assembly design shall withstand short-circuit current ability for the specified period.

NOTE 1 Under short-circuit conditions on a synchronous generator, it can be necessary to sustain a minimum value of current (after the transient disturbance has ceased) for enough time to ensure operation of the system's protective devices.

NOTE 2 Asynchronous generators deliver an occasional sustained short-circuit current only when provided with especially equipped excitation sources.

NOTE 3 Sustained short-circuit current is not necessary in cases where special relaying or other design or means are used to achieve selective protection, or where no selective protection is required.

8.4 Occasional excess current capability

Short-term excess current capability shall be in accordance with IEC 60034-1:2017, 9.3.2.

8.5 Total harmonic distortion (THD)

Limiting values of the total harmonic distortion of the line-to-line terminal voltages shall be in accordance with IEC 60034-1:2017, 9.11.

The total harmonic distortion shall be computed by using Formula (2):

$$f_{\mathrm{THD}} = \sqrt{\sum_{n=2}^{100} u_n^2} \tag{2}$$

where

u_n is the ratio of the line-to-line terminal voltage U_n of the harmonic n of the a.c. generator to the line-to-line terminal fundamental voltage U_1 of the a.c. generator;

n is the order of harmonic.

NOTE The total harmonic distortion at full linear load is expected to be less than 5 %. In such cases, the load will cause no increase of harmonics.

8.6 Emission of electromagnetic fields (EMF)

It is presupposed that a.c. generators in operation fulfil local requirements for the protection of workers from risk to their health and safety from exposure to electromagnetic field during their work.

The a.c. generator manufacturer shall evaluate radiated and conducted emission of electromagnetic fields. In case of exceeding exposure limit values (IEC 60034-1:2017, Annex B), information of risk area around the generator shall be provided.

NOTE 1 As the a.c. generator in a power plant is often a large machine having some higher magnetic fields outside the housing, it is possible to define boundaries around the generator in the machine hall, inside of which radiated or conducted electromagnetic fields can be higher than according to CISPR 11 requirements and access is forbidden for electronic devices and restricted to allowed staff only.

NOTE 2 It is understood that the power cables connected with the a.c. generator can be the main source of electromagnetic emissions.

9 Operating limits

9.1 Limits of temperature and temperature rise

Unless otherwise specified, a.c. generators shall be suitable for operation at its power rating definitions in accordance with ISO 8528-1:2018, Clause 14 at ambient air temperature up to 40 °C at an altitude not exceeding 1 000 m above sea-level.

The electrical insulation system determines the service life of generators which can be affected by electrical, thermal, mechanical or environmental stresses acting either individually or in combinations. During duty type S1 generator operation at rated load under reference conditions, the hottest point of each winding shall not exceed the agreed thermal class temperature of the insulation system.

NOTE 1 The temperature class of an electrical insulation material or system is determined by its temperature index. The temperature index is the numerical value of the Celsius temperature characterizing the thermal capability of an electrical insulation. It is derived from the thermal endurance relationship at a given time, usually 20 000 h. For further details, see IEC 60216-1.

NOTE 2 Testing has confirmed that for many electrical insulation systems, the life is reduced for a rise in temperature, and is approximately constant within a restricted temperature range dependent on the electrical insulation material involved. For most of these electrical insulation systems, the temperature rise halving the life has a value between 8 K to 15 K. For further details, see IEC 60505.

The a.c. generator manufacturer shall determine the reference service life of the generator at rated output for duty type S1.

NOTE 3 Frequent operation above the normal temperature limits (see IEC 60034-1), which cannot be prevented by built-in thermal protection without risking nuisance trips, can lead to a noticeable reduction of electrical insulation system life.

NOTE 4 The RIC engine output can vary with changes of ambient air temperature. In operation, the a.c. generator global temperature depends upon its primary coolant temperature which is not necessarily related to the RIC engine air inlet temperature.

Where the expected site conditions exceed those listed above, the generating set manufacturer shall review the conditions with the a.c. generator manufacturer to determine how the performance of the a.c. generator will be affected by unusual or harsh site conditions to ensure the a.c. generator is selected with appropriate rating adjustments and design features. In some cases, definite-purpose or special-purpose machines may be required to fulfil unusual or harsh site conditions.

9.2 Operating limit values

Four performance classes of major significance are given in Table 2 to describe the a.c. generator characteristics. The performance classes are defined in ISO 8528-1.

The values given in Table 2 apply only to the a.c. generator, exciter and automatic voltage regulator operating at constant (rated) speed and starting from ambient temperature. The effect of the prime mover speed regulation can cause these values to differ from the values given in Table 2. Annex A provides additional information for specific parameters.

Table 2 — A.c. generator operating limit values

<table>
<tr><th rowspan="2">Term</th><th rowspan="2">Symbol</th><th rowspan="2">Unit</th><th rowspan="2">Load change</th><th colspan="4">Performance class</th></tr>
<tr><th>G1</th><th>G2</th><th>G3</th><th>G4</th></tr>
<tr><td rowspan="2">Range of voltage setting</td><td rowspan="2">ΔU_s</td><td rowspan="2">%</td><td rowspan="2">[a]</td><td colspan="3">≥[±5][b]</td><td rowspan="2">AMC[d]</td></tr>
<tr><td colspan="3">≥[±10][c]</td></tr>
<tr><td>Steady-state voltage deviation</td><td>ΔU_{st}</td><td>%</td><td>[e]</td><td>≤+5</td><td>≤+2,5</td><td>≤+1</td><td>AMC</td></tr>
<tr><td>Transient voltage drop[f,g,h]</td><td>ΔU_{dyn}^-</td><td>%</td><td>0 % to 100 %[i]</td><td>≥-30[j]</td><td>≥-24[j]</td><td>≥-18[j]</td><td>AMC</td></tr>
<tr><td>Transient voltage rise[f,g,h]</td><td>ΔU_{dyn}^+</td><td>%</td><td>100 % to 0 %[i]</td><td>≤+35</td><td>≤+25</td><td>≤+20</td><td>AMC</td></tr>
</table>

[a] All loads between no-load and rated output.

[b] For a.c. generators in island mode operation. Not necessary if fixed voltage setting is not required.

[c] For a.c. generators operating parallel with the grid without step-up transformer.

[d] AMC = by agreement between a.c. generator manufacturer and generating set manufacturer.

[e] All load changes between no-load and rated output.

[f] Other power factors and limit values can be by agreement.

[g] The choice of a grade of transient voltage performance better than is actually necessary can result in a much larger a.c. generator. Since there is a consistent relationship between transient voltage performance and the sub-transient reactance parameters, the system fault level will also be increased.

[h] Higher values can be applied to a.c. generators with rated output higher than 5 MVA and rotational speeds of 600 min^{-1} or less.

[i] Load current at rated voltage, constant impedance load.

[j] This limit value differs from that in ISO 8528-5:2018, Table 4, as this value applies to a load step from 0 % to 100 %, which is not the case in ISO 8528-5.

[k] At no-load.

[l] In case of parallel operation, these values will be reduced to 0,5.

Table 2 *(continued)*

Term	Symbol	Unit	Load change	Performance class			
				G1	G2	G3	G4
Voltage recovery time[f,g]	t_{rec}	s	0 % to 100 %[i] 100 % to 0 %	≤2,5	≤1,5	≤1,5	AMC
Voltage unbalance factor	$\Delta U_{2,0}$	%	[k]	≤1[l]	≤1[l]	≤1[l]	AMC

[a] All loads between no-load and rated output.

[b] For a.c. generators in island mode operation. Not necessary if fixed voltage setting is not required.

[c] For a.c. generators operating parallel with the grid without step-up transformer.

[d] AMC = by agreement between a.c. generator manufacturer and generating set manufacturer.

[e] All load changes between no-load and rated output.

[f] Other power factors and limit values can be by agreement.

[g] The choice of a grade of transient voltage performance better than is actually necessary can result in a much larger a.c. generator. Since there is a consistent relationship between transient voltage performance and the sub-transient reactance parameters, the system fault level will also be increased.

[h] Higher values can be applied to a.c. generators with rated output higher than 5 MVA and rotational speeds of 600 min^{-1} or less.

[i] Load current at rated voltage, constant impedance load.

[j] This limit value differs from that in ISO 8528-5:2018, Table 4, as this value applies to a load step from 0 % to 100 %, which is not the case in ISO 8528-5.

[k] At no-load.

[l] In case of parallel operation, these values will be reduced to 0,5.

10 Rating plate

The a.c. generator rating plate shall comply with the requirements of IEC 60034-1. In addition, the rated output, power factor and class of rating shall be combined as follows.

a) Where a rating with continuous constant load based on duty type S1 is stated, the rated output shall be followed by the marking "S1", for example

$$S_r = 22 \text{ kVA} (\cos\varphi \ 0{,}8 \text{overexcited}) \text{S1}$$

b) Where a rating with discrete constant loads based on duty type S10 is stated, the rating with continuous constant load based on duty S1 shall be marked as in a). In addition, the peak rated output shall be shown followed by the marking "S10", the maximum running time per year and the value of the quantity T_L, for example

$$S_r = 24 \text{kVA} (\cos\varphi 0{,}8 \text{overexcited}) \text{S10}, 300 \text{h}, T_L = 0{,}90$$

Upon request, the a.c. generator manufacturer shall provide the generating set manufacturer with a capability graph or set of values showing the permissible output of the a.c. generator over the range of coolant temperature involved.

A.c. generators specified to operate parallel with the grid shall contain the marking GPO "grid parallel operation", for example:

ISO 8528-3 (GPO)

11 Bearings

11.1 General

It is the responsibility of the a.c. generator manufacturer and the generating set manufacturer to specify the a.c. generator either as a single-bearing generator or as a two-bearing generator. Based on application, the use of rolling bearings or plain bearings shall be decided by agreement between the a.c. generator manufacturer and the generating set manufacturer.

11.2 Rolling bearings

The following information shall be provided on the rating plate, separate data plate or in the accompanying manual:

— type of bearings;

— type of grease;

— quantity of grease for re-greasing;

— re-greasing interval;

— in case of an automatic greasing device the parameters to install and operate the device.

Re-greasing intervals can be aligned with generating set maintenance cycles. The rating life of the bearings shall be determined according ISO 281.

11.3 Plain bearings

Plain bearings shall be designed to ensure proper operation, lubrication and maintenance of a.c. generators. When specified by the generating set manufacturer each plain bearing shall be equipped with a temperature detector. Where applications are expected to encounter conditions or events that will accelerate babbitt wear (such as regular start-stop duties), design solutions to minimize such wear shall be considered.

The following information shall be provided on the rating plate, separate data plate or in the accompanying manual:

— number and type of bearings;

— type of lubrication oil;

— quantity of lubricant;

— oil change interval.

The replacement interval of lubrication oil can be aligned with generating set maintenance cycles.

12 Maintenance

RIC engine maintenance and a.c. generator maintenance shall be well co-ordinated to allow a lean planning of maintenance cycles and to reduce unnecessary downtime of the generating set. Therefore, the generator maintenance schedule is subject to the agreement between the a.c. generator manufacturer and the generating set manufacturer.

NOTE An efficient strategy for maintenance is condition-based maintenance (CBM) where signs of degreasing performance or imminent failure of a component are used to decide what type of maintenance to perform.

Annex A
(informative)

Transient voltage characteristic following a sudden change of load

A.1 General

When an a.c. generator is subject to a sudden load change, there will be a resultant time-varying change in the terminal voltage. One function of the exciter-regulator system is to detect this change in the terminal voltage and to vary the field excitation as required to restore the terminal voltage. The maximum transient deviation in the terminal voltage that occurs is a function of:

a) the magnitude, power factor and rate of change of the applied load;

b) the magnitude, power factor and current versus the voltage characteristic of any initial load;

c) the response time and voltage forcing capability of the exciter-regulator system;

d) the RIC engine speed versus time following the sudden load change.

Transient voltage performance is therefore a system performance characteristic involving the a.c. generator, exciter, regulator and RIC engine and cannot be established based on a.c. generator data alone. This annex covers only the a.c. generator and exciter regulator system.

When selecting or applying a.c. generators, the maximum transient voltage deviation (voltage dip) following a sudden increase in load is often specified or requested. When requested by the generating set manufacturer, the a.c. generator manufacturer shall furnish the expected transient voltage deviation, assuming either of the following criteria applies:

— the a.c. generator, exciter, and regulator are furnished as an integrated package by the a.c. generator manufacturer, or

— complete data defining the transient performance of the regulator (and exciter if applicable) is made available to the generating set manufacturer.

When furnishing the expected transient voltage deviation, the following conditions shall be assumed unless otherwise specified:

— constant (rated) speed;

— a.c. generator, exciter, regulator initially operating at the no-load, rated voltage, starting from ambient temperature;

— application of a constant impedance linear load as specified.

NOTE The expected transient voltage deviation from the rated voltage refers to the average voltage change of all phases at the a.c. generator terminals, i.e. it takes no account of asymmetry which is influenced by factors beyond the control of the a.c. generator manufacturer.

A.2 Voltage recorder performance

The following specifications are required:

— response time less than or equal to 1 ms;

— sensitivity greater than or equal to 1 % mm^{-1}.

NOTE When peak-to-peak recording instruments are used, readings of the steady-state terminal voltage before and after load application can be made with an rms-indicating instrument to determine the minimum transient voltage (see Figure A.4).

A.3 Motor starting loads

A.3.1 General

The test conditions specified in A.3.2 are recommended for demonstrating the capability of a synchronous generator, exciter, and regulation system for starting a motor.

A.3.2 Load simulation

Test conditions for load simulation are as follows:

— constant impedance (non-saturable reactive load);

— power factor less than or equal to 0,4 overexcited.

NOTE The current drawn by the simulated motor starting load can be corrected by the ratio U_r/U_{rec} whenever the a.c. generator terminal voltage fails to return to the rated voltage. This corrected value of current and rated terminal voltage can be used to determine the actual kVA load applied.

A.3.3 Temperature

The test can be conducted with the a.c. generator and exciter system initially at ambient temperature.

A.4 Presentation of data

Transient voltage regulation performance curves can be plotted as "voltage dip", expressed as a percentage of the rated voltage versus 'kVA load' (see Figure A.1).

The performance characteristics vary considerably for broad voltage range a.c. generators when operating over the full range of their adjustment. Therefore, the percent voltage dip versus kVA load curve provided for broad voltage range a.c. generators shows the performance at the extreme ends of the operating range, i.e. 208 V to 240 V / 416 V to 480 V. For discrete voltage a.c. generators, the percent voltage dip versus kVA load curve shows the performance at the discrete rated voltage(s).

Unless otherwise noted, the percent voltage dip versus kVA load curve provides a voltage recovery to at least 90 % of the rated voltage. If the recovery voltage is less than 90 % of the rated voltage, a point on the voltage dip curve beyond which the voltage will not recover to 90 % of the rated voltage can be identified or a separate voltage recovery versus kVA load curve can be provided.

In the absence of a.c. generator manufacturer information, the value of voltage dip can be estimated from machine constants:

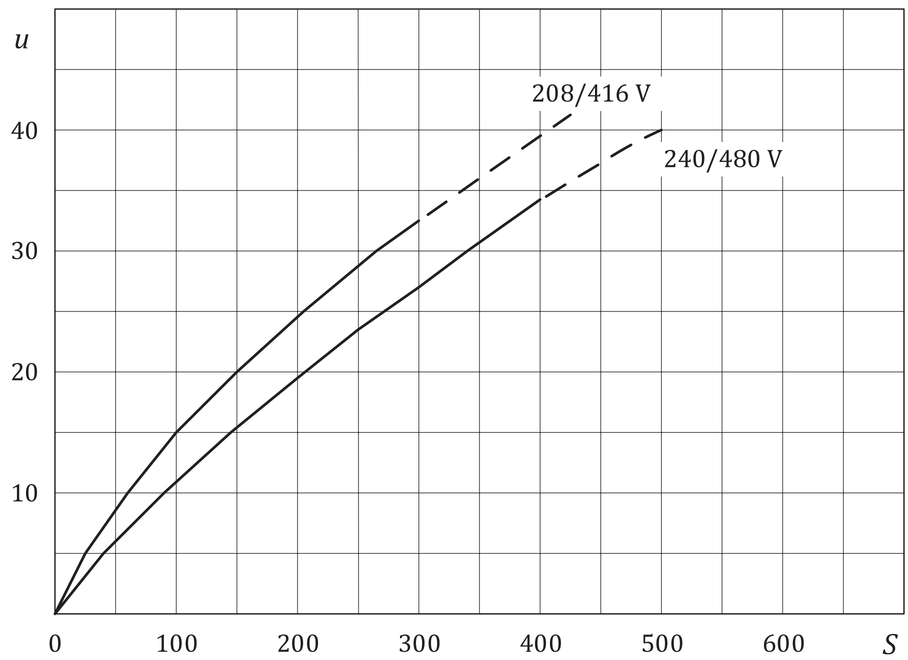
$$u = \frac{X'_d}{X_L + X'_d} \cdot 100\% \quad \text{(A.1)}$$

where

u is the voltage dip in percent;

X'_d is the direct axis transient reactance in per unit;

X_L is the applied load in per unit on generator kVA base.



Key

S load in kVA

u voltage dip in percent of the rated voltage
(dashed line indicates recovery voltage less than 90 %)

NOTE Performance curves are provided at $\cos\varphi \leq 0,4$.

Figure A.1 — Example of performance curves for step loading

A.5 Examples

Strip charts of the output voltage as a function of time demonstrate the transient performance of the a.c. generator, exciter, regulation system to sudden changes in load. Recording the entire voltage envelope determines the performance characteristics.

Strip charts representing two types of voltage recorder are illustrated in Figures A.2, A.3 and A.4. The labelled charts and sample calculations can be used as a guide to determine the generator-exciter-regulator performance when subjected to a sudden load change.

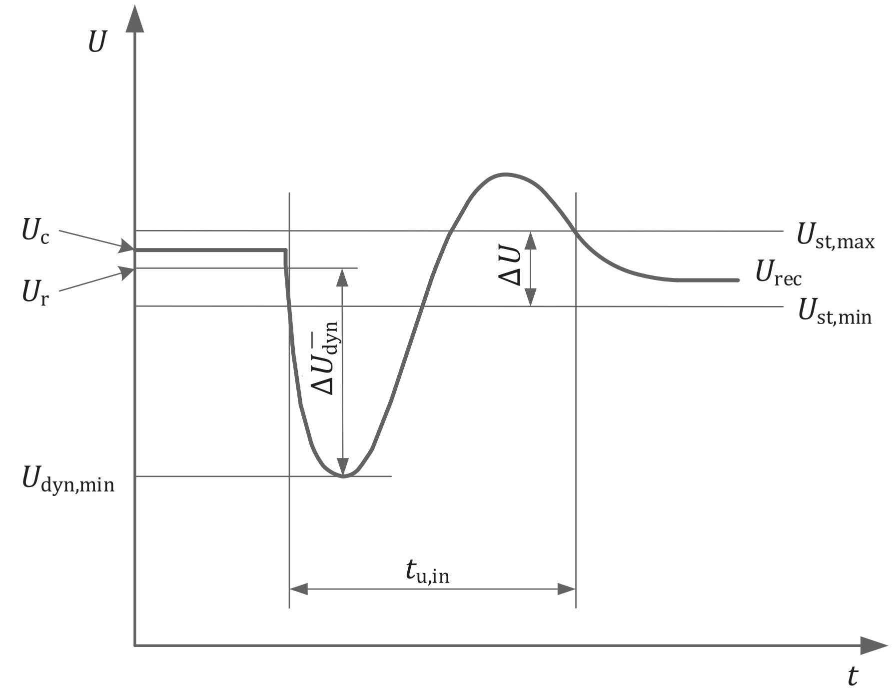


Figure A.2 — Transient voltage characteristic for load increase (rms voltage versus time)

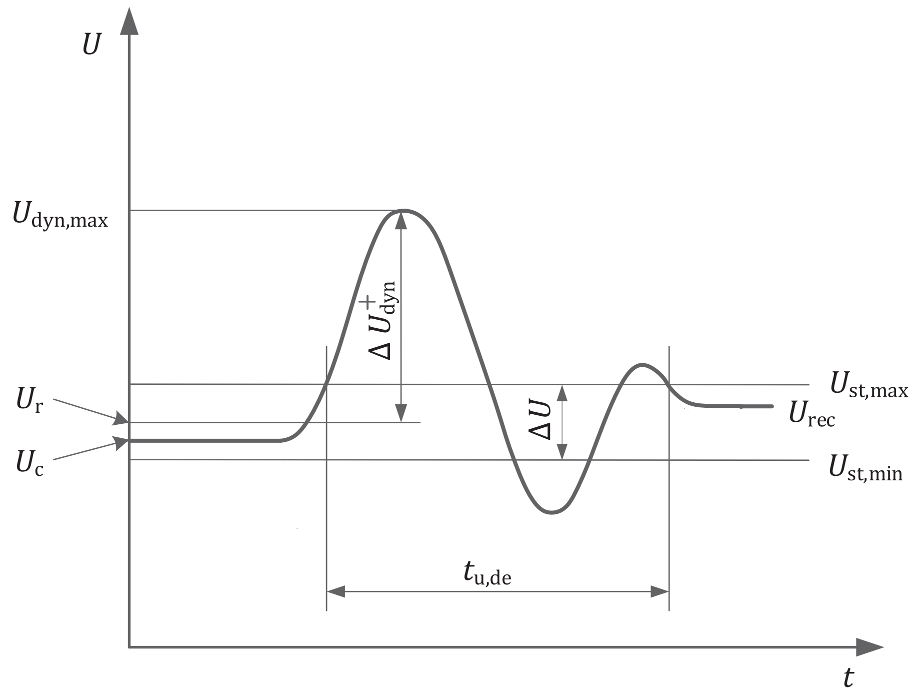
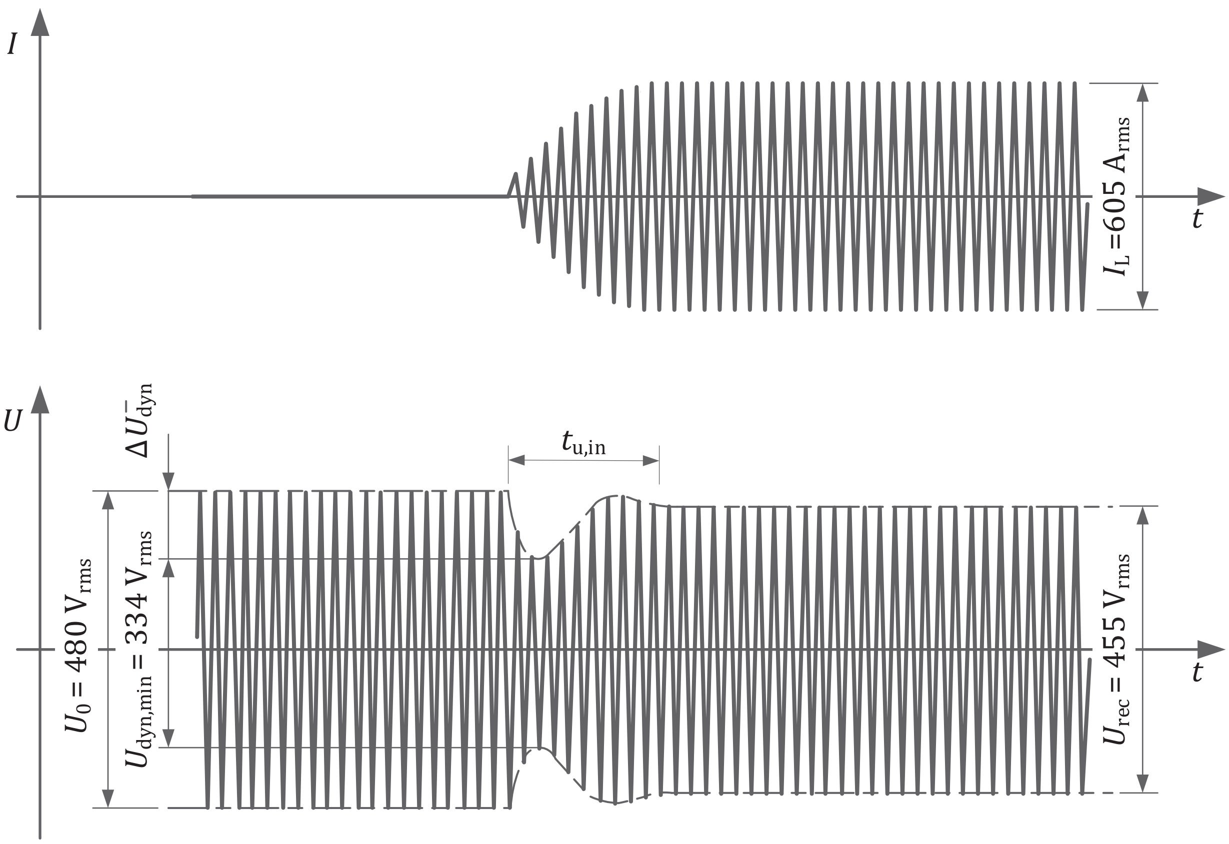


Figure A.3 — Transient voltage characteristic for load decrease (rms voltage versus time)



Key

I_L real current drawn by the load

I'_L current drawn by the load corrected to the rated voltage

EXAMPLE:

$U_r = U_0 = 480 V_{rms}$

$U_{dyn,min} = 334 V_{rms}$

$U_{rec} = 455 V_{rms}$

$I_L = 605 A$

$$\Delta U^-_{dyn} = \frac{U_{dyn,min} - U_r}{U_r} \cdot 100 = \frac{334 V - 480 V}{480 V} \cdot 100 = -30,4\%$$

$$I'_L = I_L \cdot \frac{U_r}{U_{rec}} = 605 A \cdot \frac{480 V}{455 V} = 638 A$$

Figure A.4 — A.c. generator transient voltage versus time curve for sudden load increase (instantaneous voltage versus time)

Bibliography

[1] ISO 8528 (all parts), *Reciprocating internal combustion engine driven alternating current generating sets*

[2] IEC 60050 (all parts), *International Electrotechnical Vocabulary*

[3] IEC 60216-1, *Electrical insulation materials — Thermal endurance properties — Part 1: Ageing procedures and evaluation of the results*

[4] IEC 60505, *Evaluation and qualification of electrical insulation systems*

[5] IEC/TS 62786, *Distributed energy resources connection with the grid*

[6] CISPR 11, *Industrial, scientific and medical equipment — Radio-frequency disturbance characteristics — Limits and methods of measurement*

(*Continued from second cover*)

In this adopted standard reference appears to certain International Standard for which Indian Standard also exist. The Corresponding Indian Standard which are to be substituted in its place is given below along with their degree of equivalence for the edition indicated:

International Standard	*Corresponding Indian Standard*	*Degree of Equivalence*
ISO 281 Rolling bearings — Dynamic load ratings and rating life	IS 3824 : 2007 Rolling bearings — Dynamic load ratings and rating life	Identical
ISO 8528-1 : 2018 Reciprocating internal combustion engine driven alternating current generating sets — Part 1: Application, ratings and performance	IS/ISO 8528-1 : 2018 Reciprocating internal combustion engine driven alternating current generating sets: Part 1 Application, ratings and performance	Identical
IEC 60034-1 : 2017 Rotating electrical machines — Part 1: Rating and performance	IS/IEC 60034-1 Rotating electrical machines: Part 1 Rating and performance (*Under preparation*)	Identical
IEC 60034-5 Rotating electrical machines — Part 5: Degrees of protection provided by the integral design of rotating electrical machines (IP code) — Classification	IS/IEC 60034-5 : 2000 Rotating electrical machines: Part 5 Degrees of protection provided by the integral design of rotating electrical machines (IP code) — Classification	Identical to year 2000 version
IEC 60034-6 Rotating electrical machines — Part 6: Methods of cooling (IC Code)	IS 6362 : 1995 Designation of methods of cooling of rotating electrical machines	Identical

The technical committee responsible for the preparation of this standard has reviewed the provisions of the following mentioned ISO/IEC standards and has decided that they are acceptable for use in conjunction with this standard:

International Standard/ Other Publication	*Title*
IEC 60034-7	Rotating electrical machines — Part 7: Classification of types of construction, mounting arrangements and terminal box position (IM Code)

Attention is drawn to the possibility that some of the elements of this standard may be the subject of patent rights. The Bureau of Indian Standards shall not be held responsible for identifying any or all such patent rights.

Annex A is for information only.

In reporting the result of a test or analysis made in accordance with this standard, if the final value, observed or calculated, is to be rounded off it shall be done in accordance with IS 2 : 2022 'Rules for rounding off numerical values (*Second Revision*)'.

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